Fermilab

Modeling of the Booster Cavity with an Eye to Improving Reliability

Mohamed Awida Hassan

SRF Department, Technical Divsion

On Behalf of Timergali Khabiboulline , Vyacheslav Yakovlev, Valeri Lebedev, and Mark Champion

Outline

- Motivation: Proton Improvement Plan
- Challenges of the PIP for the Booster Cavity
- Geometry of Booster Cavity/Material Properties
- Modeling Effort
- Conclusion

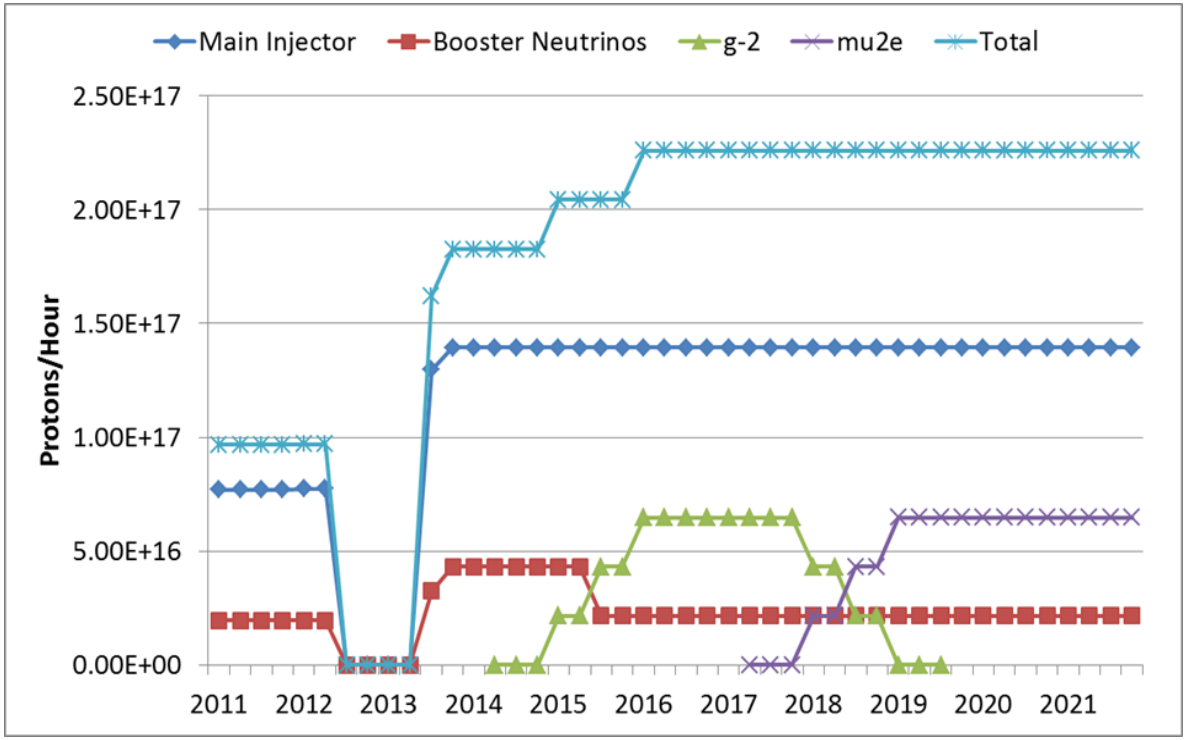
Motivation: Proton Improvement Plan

- Objectives: *Increase the Proton Source throughput while maintain good availability and acceptable residual activation through 2025.*

FermiLab
AD/Proton Source Dept.
PIP
Proton Improvement Plan

Specific Goals

- deliver **1.80E17** protons per hour (**12 Hz**) by **May 1, 2013**
- deliver **2.25E17** protons per hour (**15 Hz**) by **January 1, 2016**
- while maintaining Linac/Booster availabilty **> 85%**



S. Henderson, Accelerator Advisory Committee, Nov. 7-9, 2011

Challenges of the PIP for the Booster Cavity

	Current	Modified
Frequency Range	37.80-52.82 MHz	Same
V_{acc}	55 KV	60 KV
R/Q	~50	~50
Duty Cycle	Effectively 25%	50%
Repetition Rate	Effectively 7 Hz	15 Hz
Cavity Tuning	Horizontal Bias	Same
Beam Pipe Diameter	2.25”	>3”
Higher Order Mode Impedance	<1000 Ohm	<1000 Ohm
Cooling	LCW at 95 F, Water flow up to 21 gpm	Same

Activation Problem

- Current beam pipe (2.25”) is vulnerable to activation
- Need to increase the beam pipe size (3”)

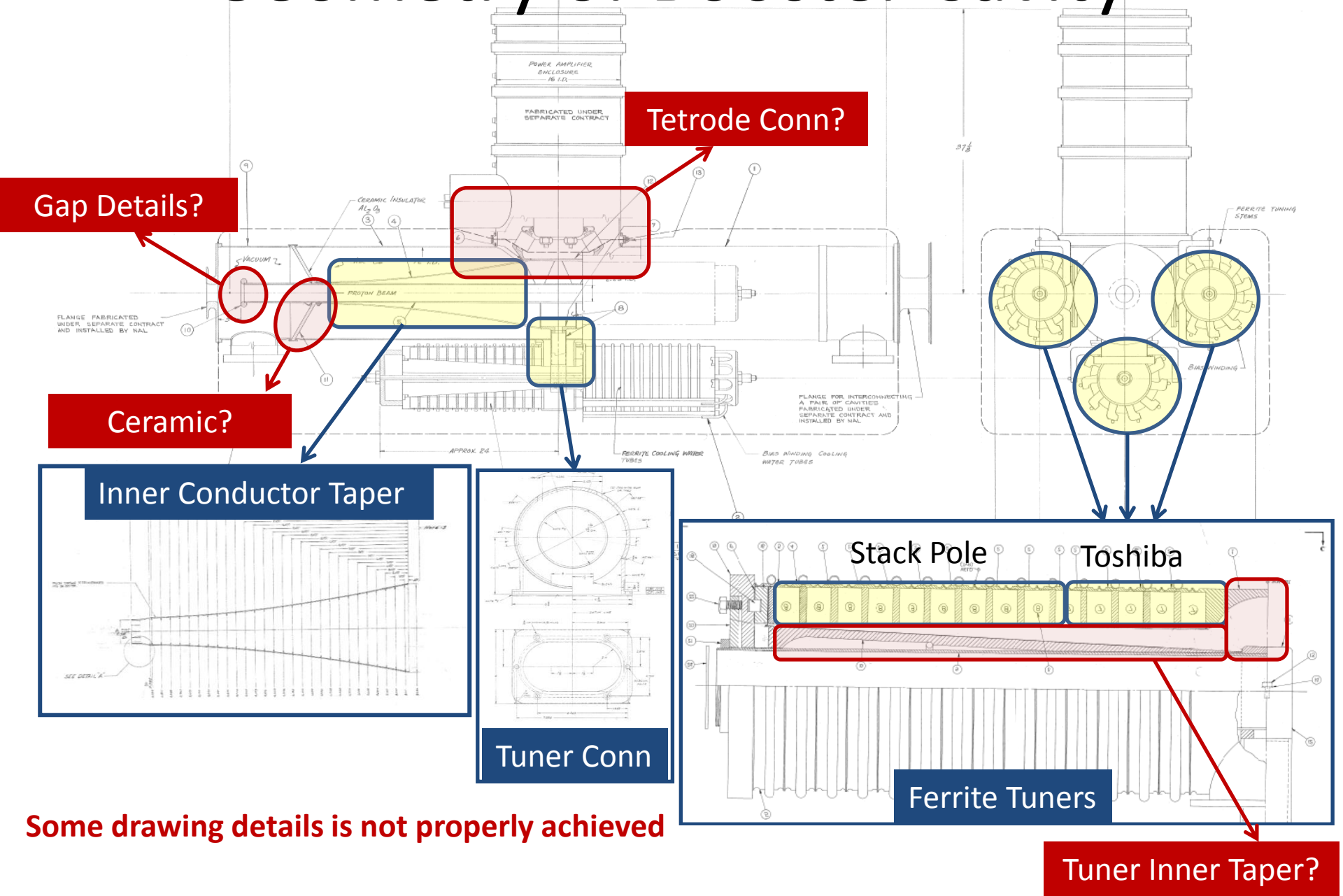
Heating Problem

- Need to double the repetition rate to 15 Hz
- Current cooling mechanism may not tolerate the additional heating in tuners

Breakdown Problem

- Need to increase the current Gap Voltage
- Weak points of max fields in Vacuum and Air will be more susceptible to break down

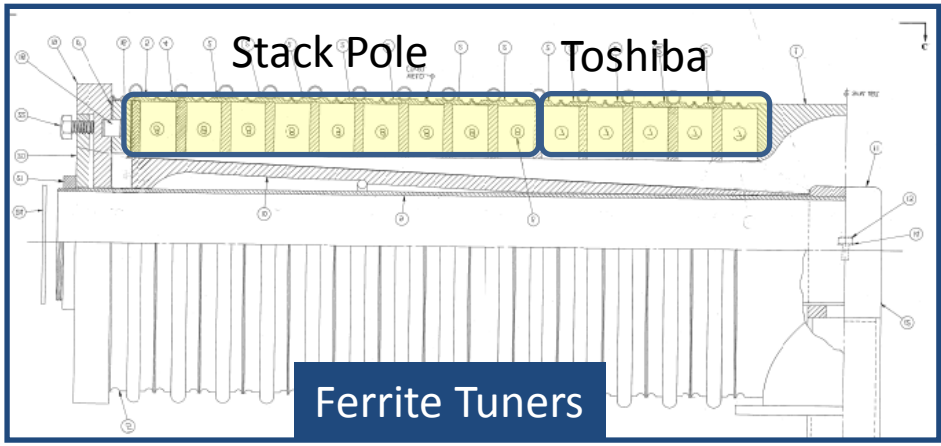
Geometry of Booster Cavity



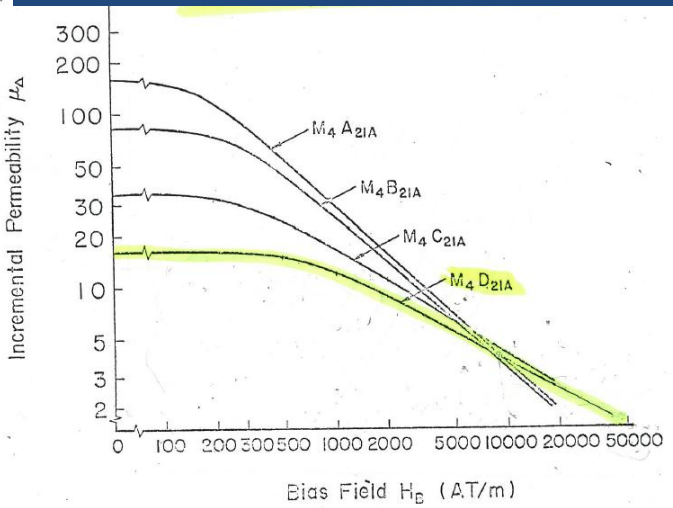
Some drawing details is not properly achieved

Ferrite Material Properties

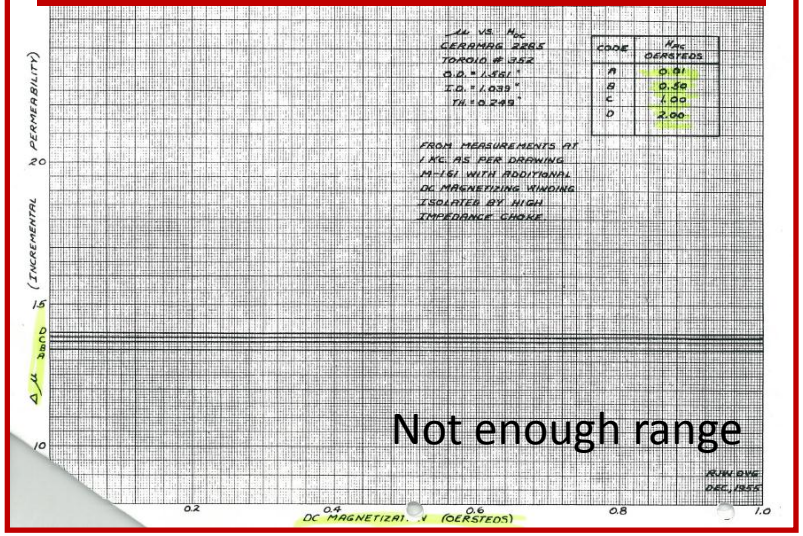
	Stack Pole	Toshiba
μ_{max}	12.5	20
Magnetic Loss Tangent @ 50 MHz	0.005	0.007
Dielectric Const	10.5	12
Dielectric Loss Tangent @ 50 MHz	0.005	0.005



Toshiba Differential Permeability



Stack Pole Differential Permeability

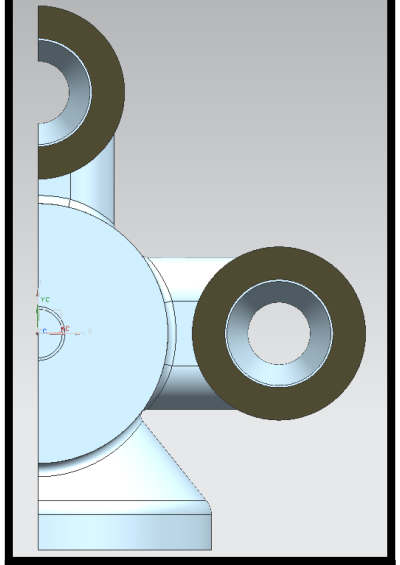


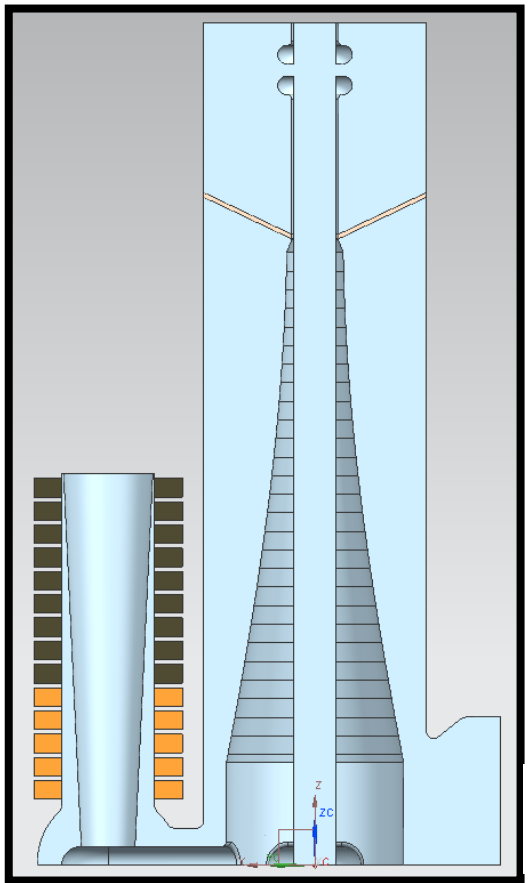
Due to the lack of available material info, typical properties of Ni-Zn ferrites are assumed

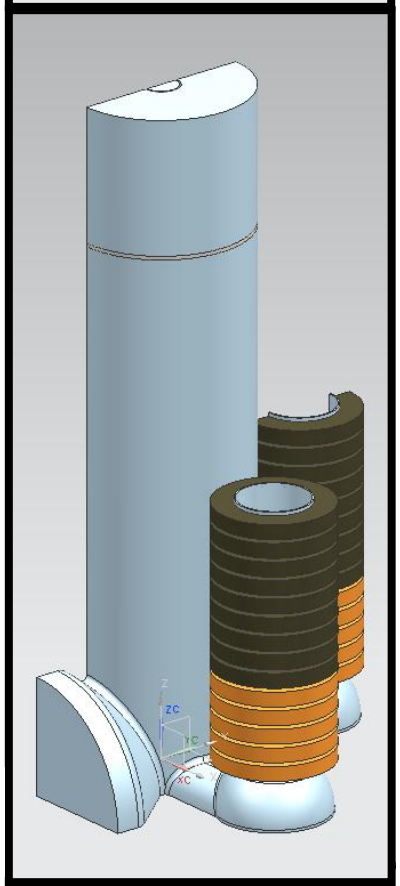
Some Material Properties are Still Missing

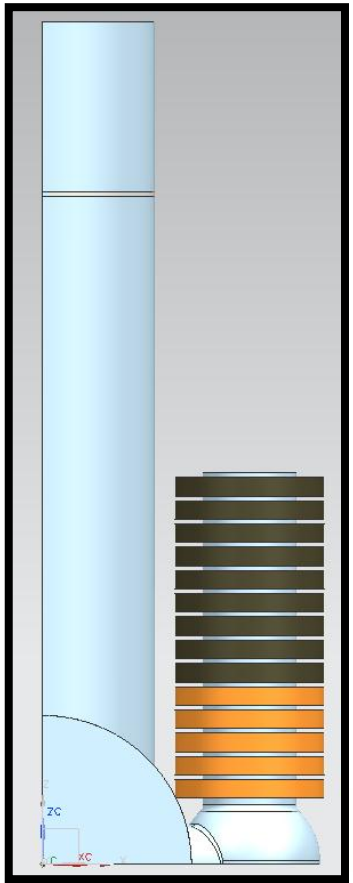
Full Detailed Model

- Realistic Tuner with all the fine details
  - 5 Toshiba Ferrites
  - 9 Stackpole Ferrites
  - Flared Inner Conductor
- Realistic Tuner Connection



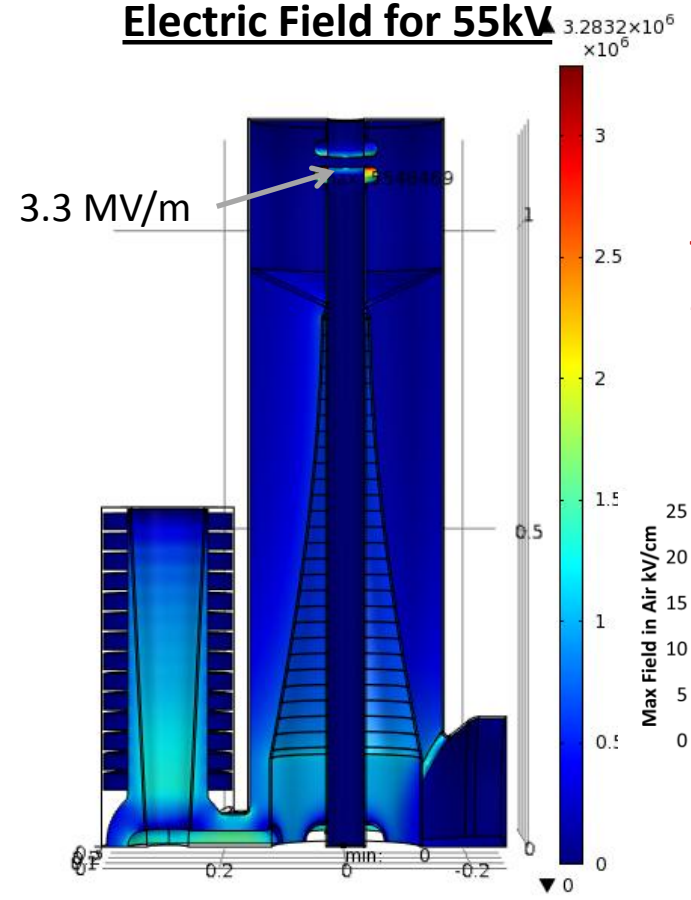




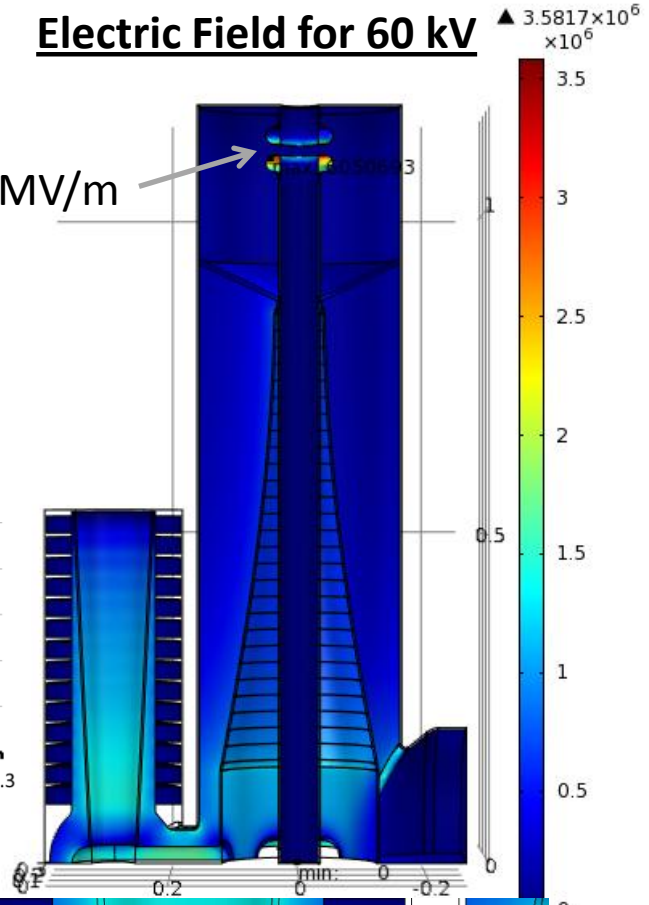


Max Electric Field

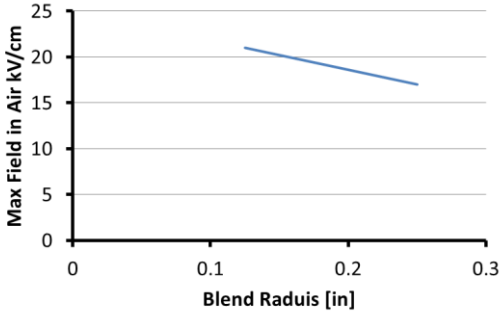
Electric Field for 55kV



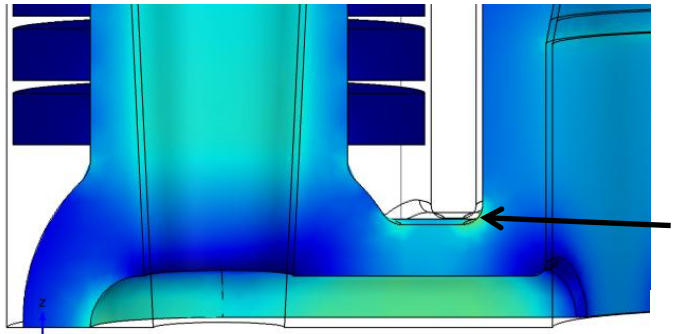
Electric Field for 60 kV



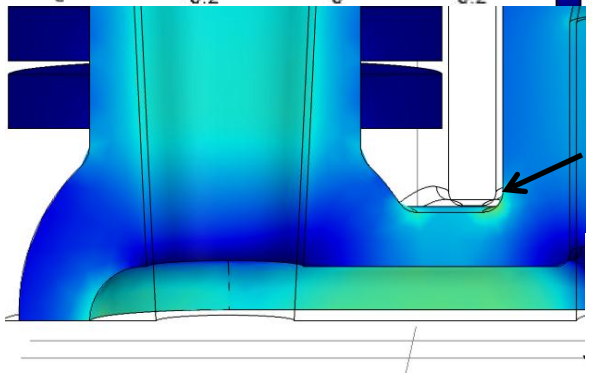
Theoretical Kilpatrick
~10 MV/m



Breakdown Voltage
~3 MV/m
~30 kV/cm



1.7 MV/m
17 kV/cm

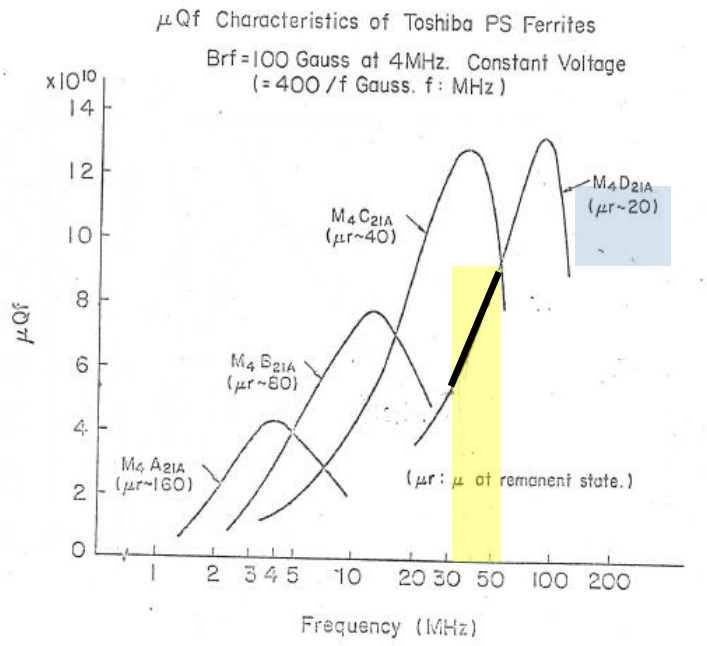


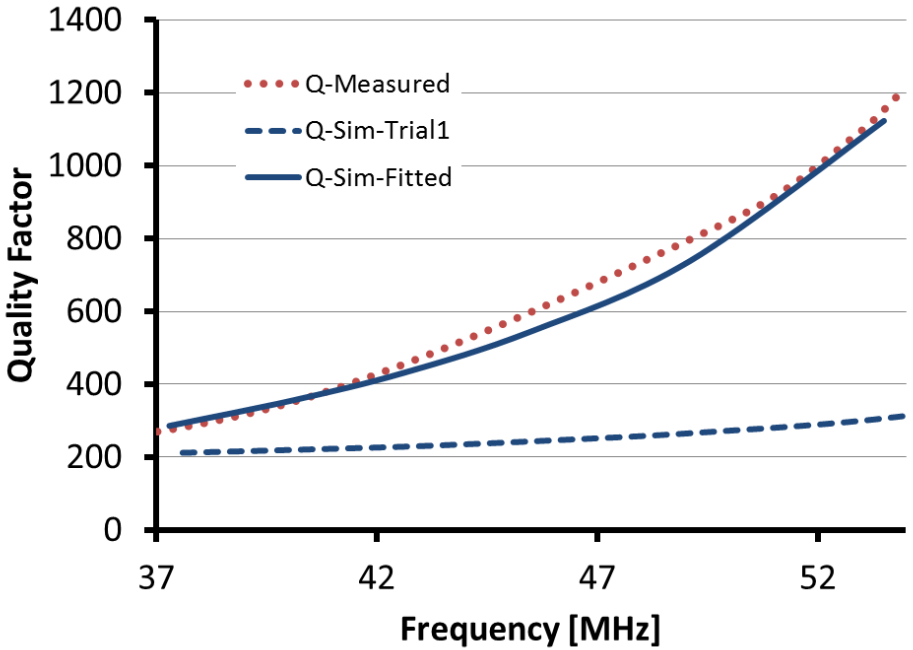
1.85 MV/m
18 kV/cm

Adjusting the Simulated Q-curve

- Total power loss is a higher than expected mainly because the simulated Q factor is lower than the measured values
- Losses of the Ferrites are strongly dependent on frequency
- Simulated Q has been fitted to the measured one by adjusting the magnetic loss tangent with frequency

- $\mu_{toshiba}=8.4$
- $\mu_{stackpole}=\mu_{toshiba}*12.5/20$
- $\delta_{m\text{-}toshiba0}=0.007$
- $\delta_{m\text{-}stackpole0}=0.005$
- $\delta_{m\text{-}toshiba}=\delta_{m\text{-}toshiba0}*\mu_{toshiba}/11.5$
- $\delta_{m\text{-}stackpole}=\delta_{m\text{-}stackpole0}*\mu_{stackpole}/(11.5/20*12.5)$

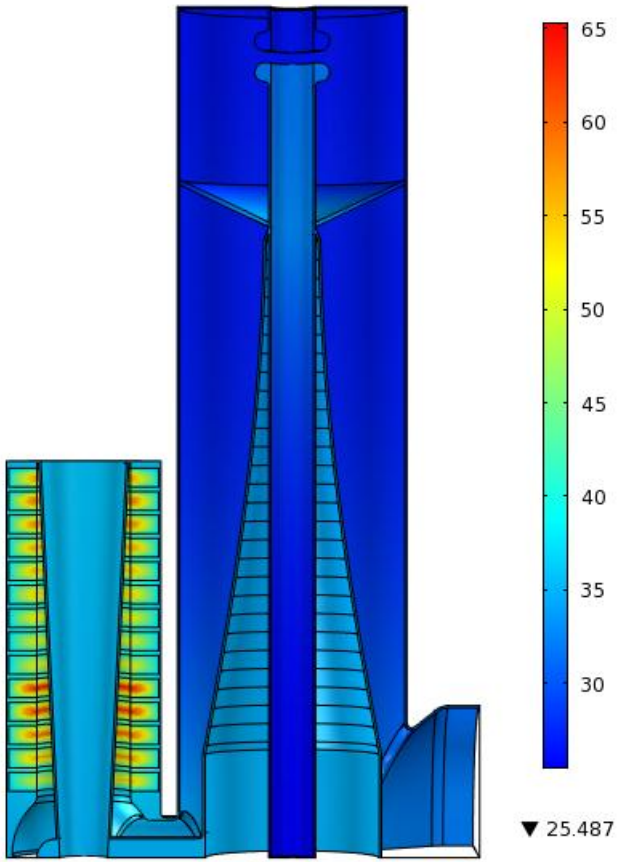




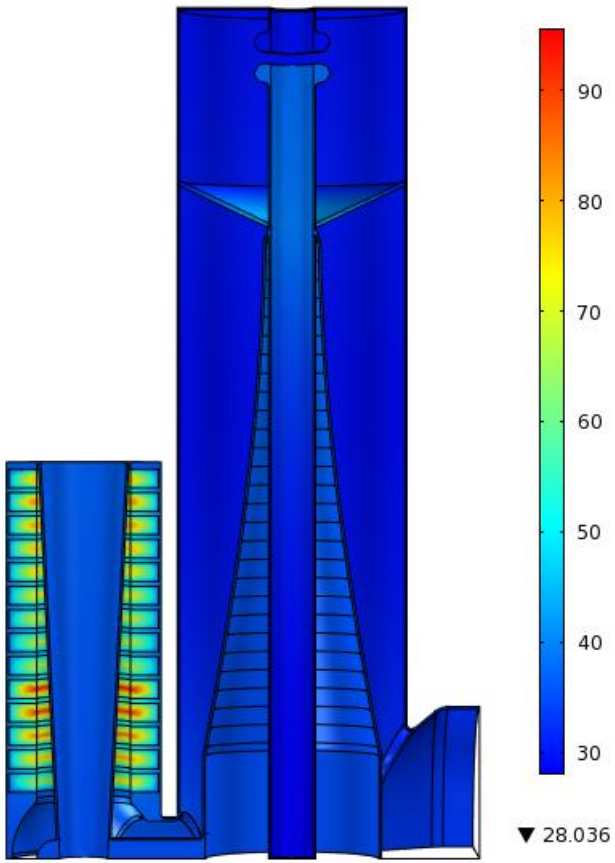
Thermal Profile for Various Scenarios of Operation

*Temperature in deg C

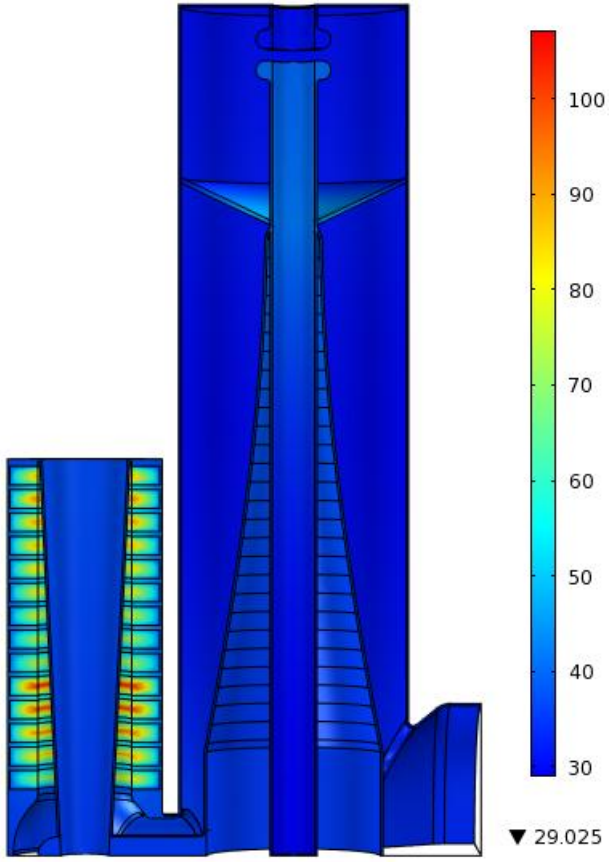
55 KV, 7Hz



55 KV, 15Hz



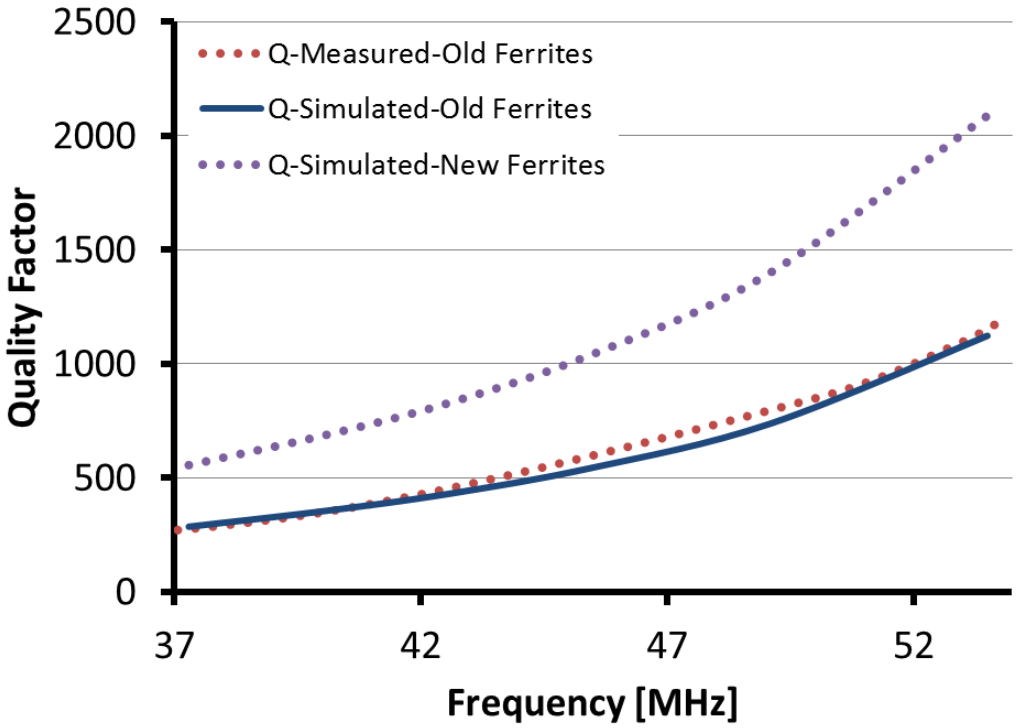
60 KV, 15Hz



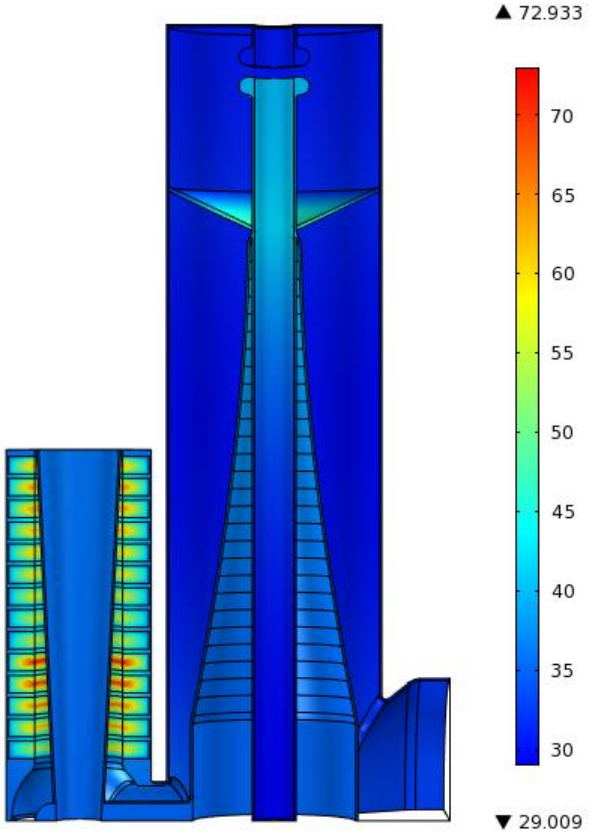
	55 KV, 7 Hz	55 KV, 15 Hz	60 KV, 15 Hz	Units
Total Losses	16.6	32.8	39.1	kW

New Ferrites

- Assuming that the new ferrites would be better in Quality factor (double)



New Ferrites, 60 KV, 15Hz



Conclusion

- If there a problem of breakdown in Air, it could be resolved by properly blending the stem connecting edges to the cavity
- 0.25” Blend radius seems to work fine even if we increased the gap voltage to 60 kV (18.5 kV/cm)
- Losses of the cavity at 7 Hz operation with 55 kV is about 16.6 kW inducing heating in the tuners of max temperature 65° C (149° F)
- Losses of the cavity at 15 Hz operation with 55 kV is projected to increase to 32.8 kW inducing heating in the tuners of max temperature is 96° C (205° F)
- Losses of the cavity at 15 Hz operation and with 60 kV is projected to increase to 39 kW inducing heating in the tuners of max temperature is 107° C (224° F)
- Better ferrites with lower loss factors (higher Q’s) would definitely help to reduce the losses and so mitigate the increased RF heating with 15 Hz operation